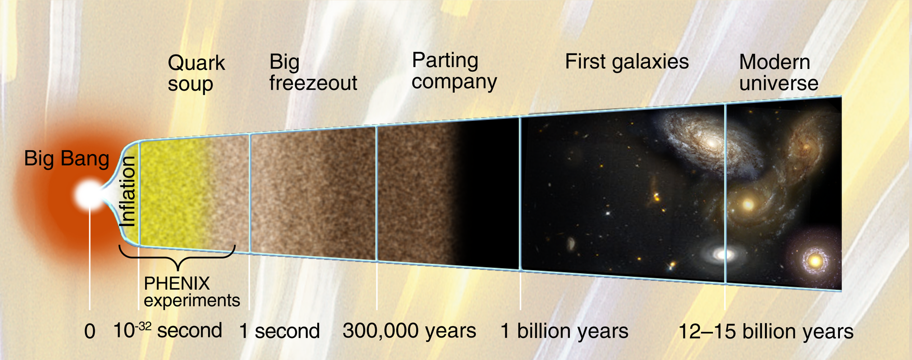
PHENIX: The Search for a New State of Matter

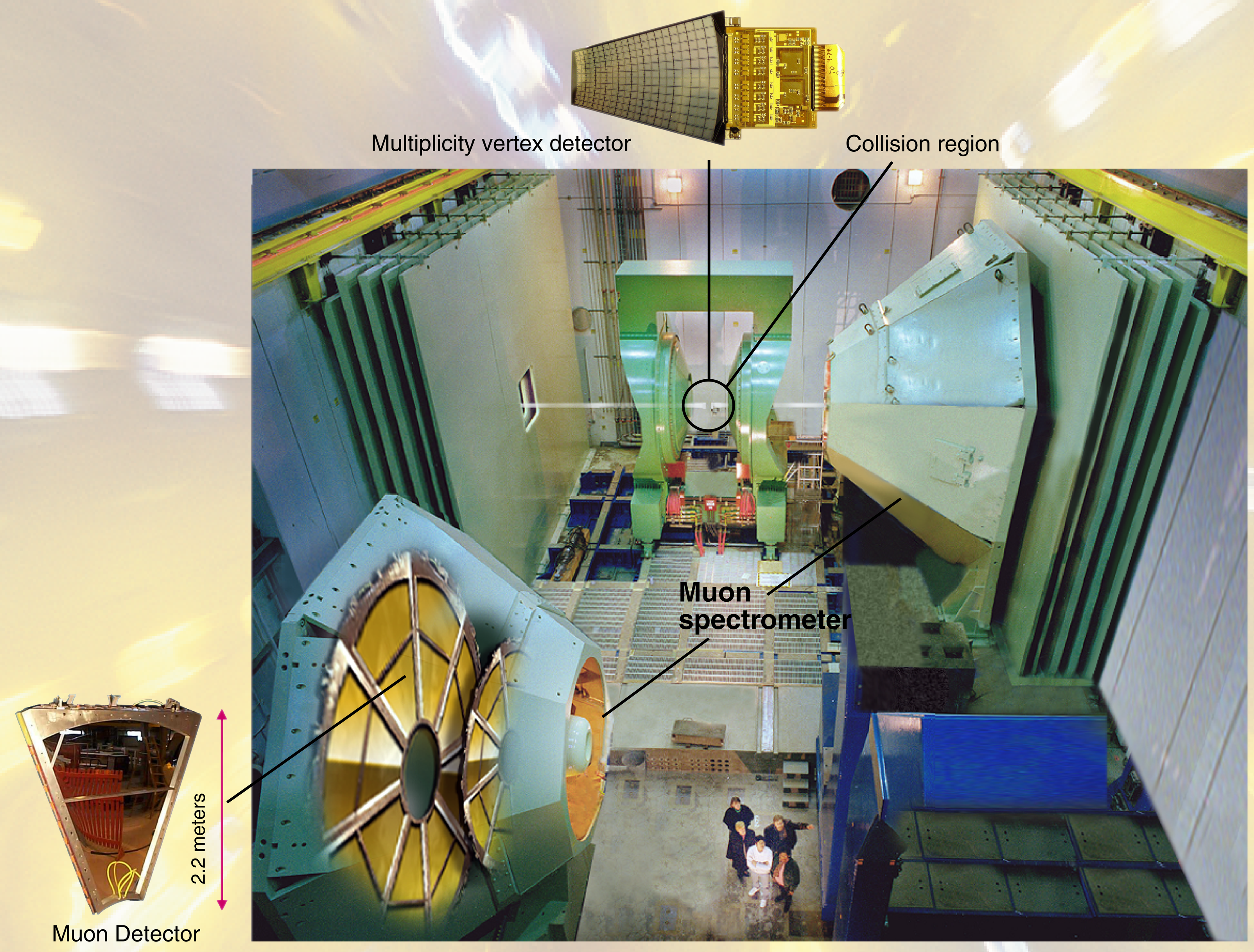


Time evolution of the Big Bang. Scientists hope to recreate the QGP, which is hypothesized to have existed for the first 10 microseconds after the initial Big Bang. Experiments at the RHIC concentrate on the reactions that occurred between the initial Big Bang and about one second, as indicated on the chart.

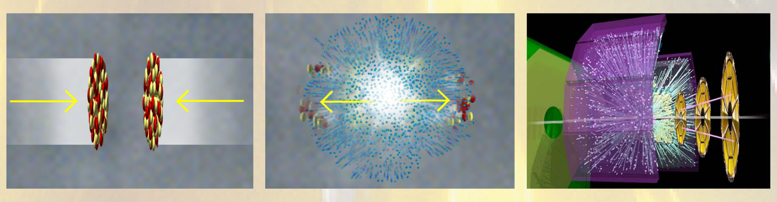
Our universe was born in a fraction of a second as a powerful explosion, a "Big Bang," filled all of space with a multitude of particles. The temperature of the universe in the first few microseconds of its existence was so hot that even the components of atomic nuclei, protons and neutrons, could not be held together. Scientists believe that during this early stage the universe consisted of a plasma of truly elementary particles: quarks, the fundamental building blocks of protons and neutrons, and gluons, particles that bind quarks together. As this quark-gluon plasma (QGP) expanded and cooled over time, the quarks and gluons condensed to form protons and neutrons that are part of ordinary matter today. The QGP is the object of an intense study by an international scientific community at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory. One of the goals of this study is to mimic the conditions that existed during the first few microseconds after the Big Bang by attempting to produce a QGP in an experimental apparatus known as PHENIX.

The RHIC complex accelerates gold ions to nearly the speed of light. When two gold ions collide head on, the conditions are produced are hotter than the sun's center and, for a fleeting moment, thought to be sufficient to form a QGP. The PHENIX detector records the particles produced during these "little Big Bangs." Staff members from the Physics Division designed and constructed three of the PHENIX detector systems—a multiplicity vertex detector (MVD) and two muon spectrometers— which are currently looking for distinct signatures of a QGP. One such signature would be the diminished production of the J/Ψ—a particle consisting of a c and c.

The PHENIX Detector



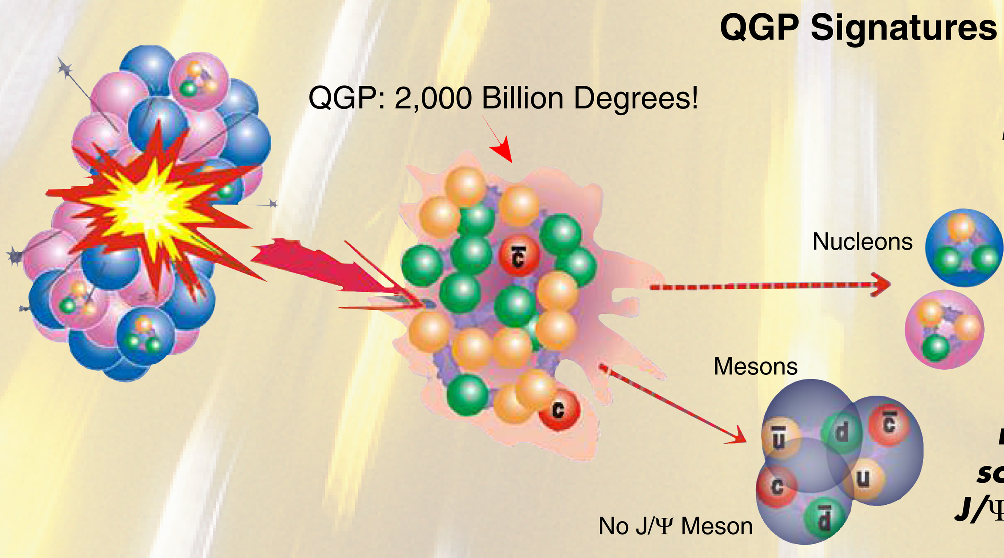
Gold-Gold Ion Collision



Collision Region | Quark-gluon Plasma | Reconstructed J/Ψ Event

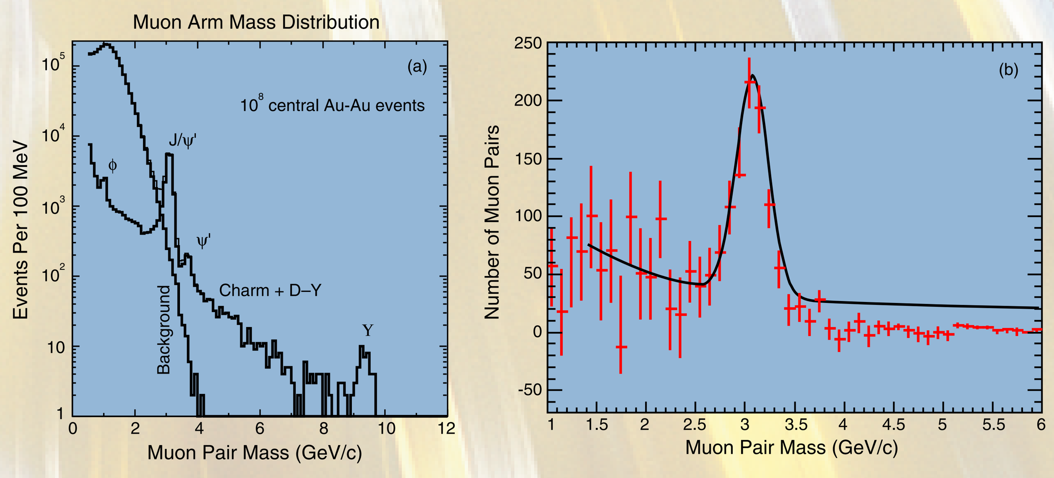
The locations of the muon spectrometers are shown in the image. The lower three images show the time evolution of a gold-gold (ion) collision and tracks from a reconstructed gold-gold collision. In the first two frames, two highly energetic gold ions collide in the PHENIX collision region. If the temperature and density are large enough, the gold ions may "dissolve" into a plasma consisting of free quarks and gluons. As the plasma expands and cools, the quarks and gluons recombine into particles of cold nuclear matter, which is eventually detected by the PHENIX detectors. The third frame shows all the tracks of the event that can be seen by the central (purple) detectors and shows two tracks from a candidate J/Ψ event in the muon arm region.

QGP Signatures



In nuclear collisions (left), charm (c) and anti-charm (c) quarks are sometimes formed. In ordinary nuclear environments, these often pair up to form J/Ψ particles. In a QGP (center), however, the abundance of other free quarks screens them from each other. Instead, the charm quarks pair up with the more common up or down quarks to form so-called D mesons (bottom right) and thus J/Ψ particles will be strongly suppressed.

Using pairs of detected muons, scientists can construct the mass of the parent particle. Shown in the upper right (a) is a simulated mass spectrum showing various reconstructed particles, including the J/Ψ, on top of continuum backgrounds. On the left (b) is a measured mass spectrum(zoomed in on the J/Ψ peak) obtained from recent deuteron-gold ion collision data. The deuteron-gold collisions, where no excessive suppression of J/Ψ particles is expected, are used as a control experiment for the gold-gold collision experiments. Physics Division scientists have now established a baseline for J/Ψ production at RHIC and are currently taking data to measure the J/Ψ yield in gold-gold collisions.



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